Marine Debris Plastics

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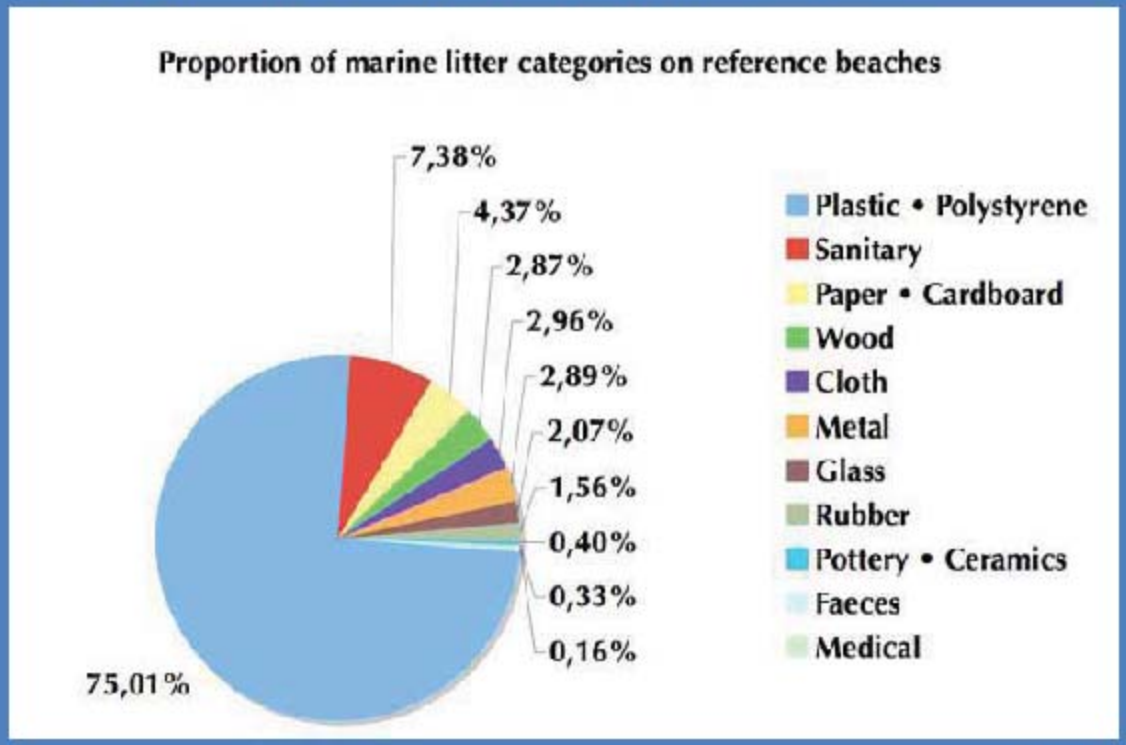
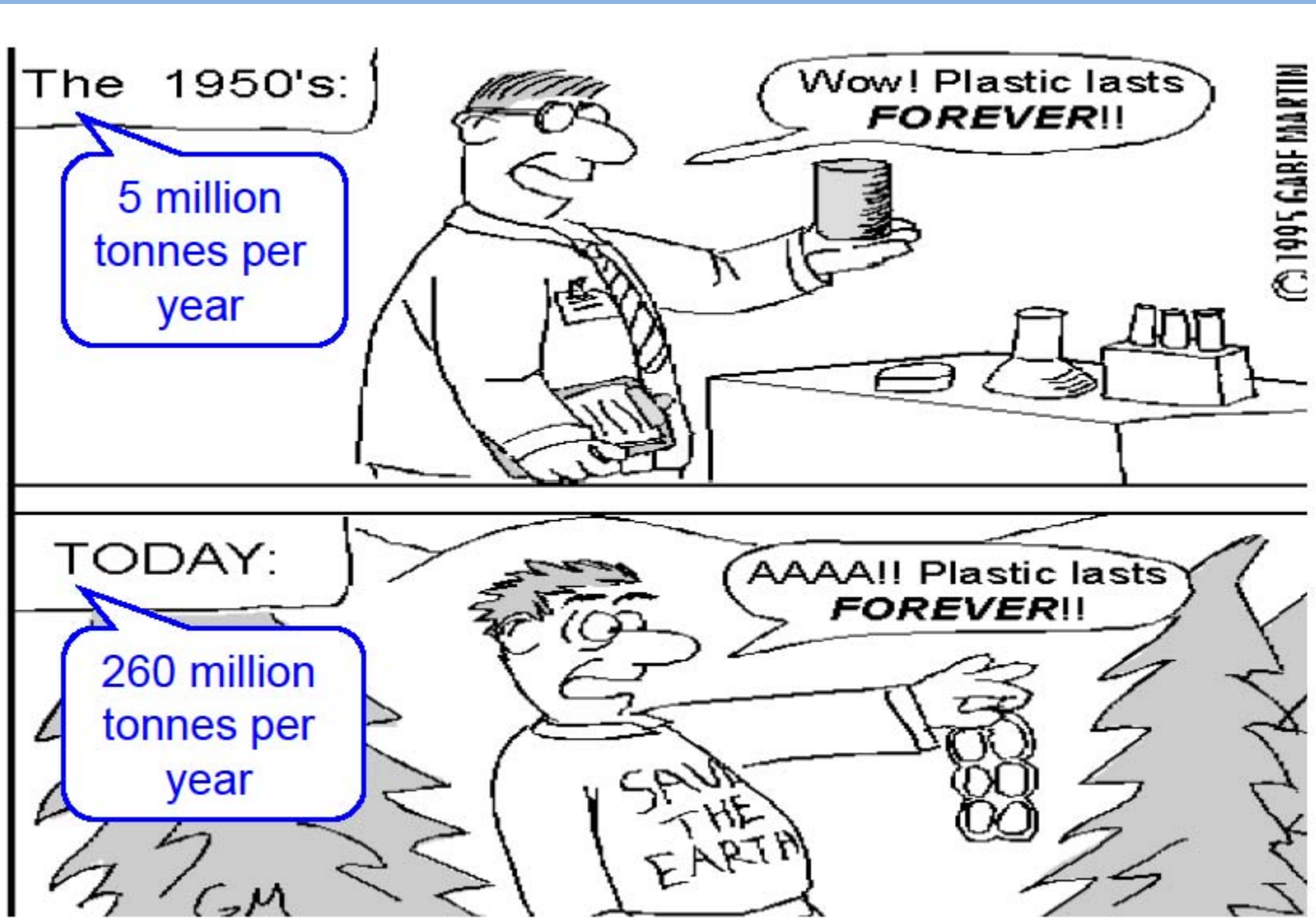
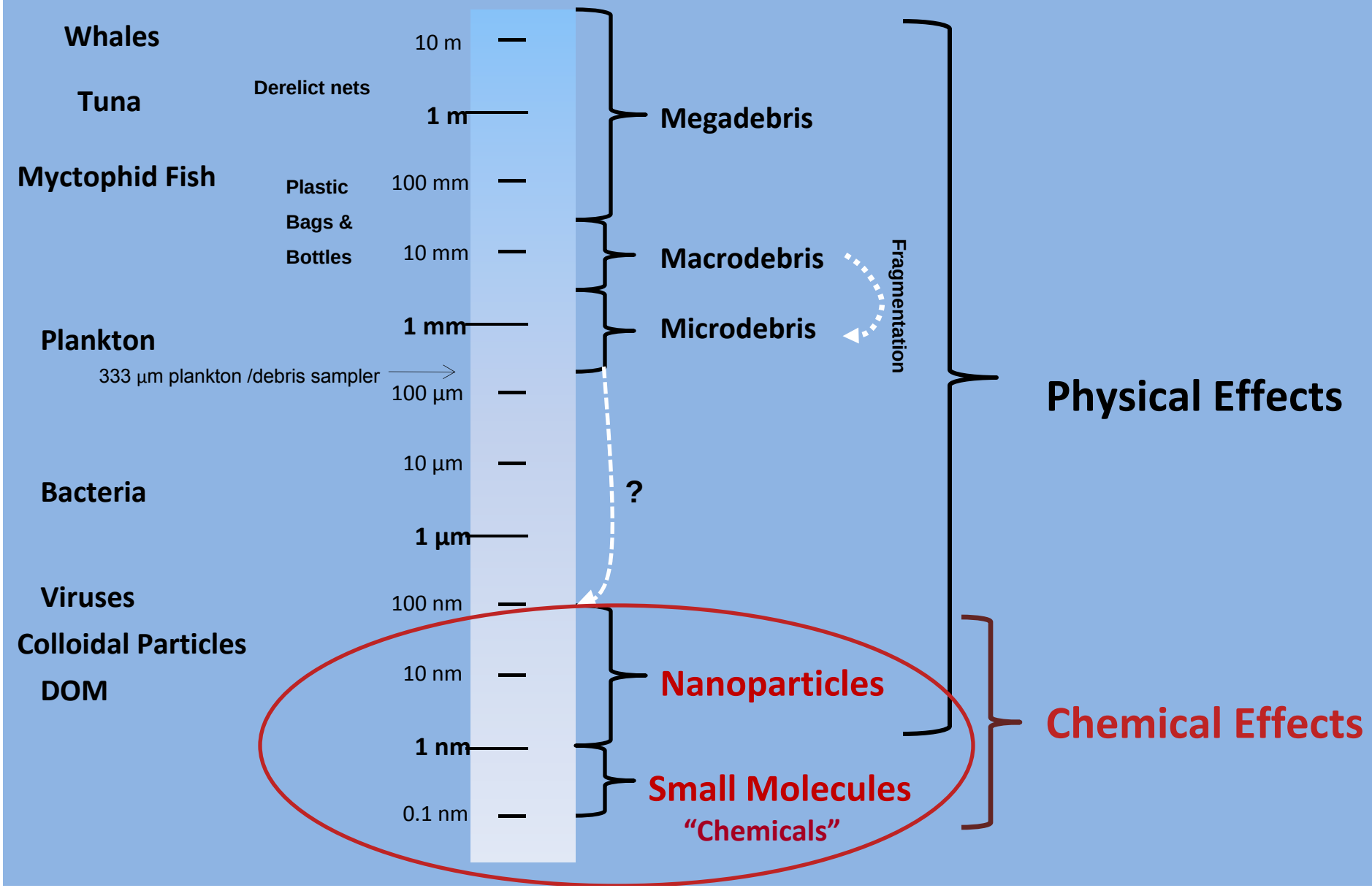
Marine debris: any form of manufactured or processed material discarded, disposed of or abandoned in the marine environment. It consists of items made or used by humans and then deliberately or unintentionally lost to the sea including transport of these materials by rivers, drainage, sewage systems or by wind.



OSPAR 2009


The 1950's:
5 million tonnes per year
Wow! Plastic lasts FOREVER!!
©1995 GARF MARTIN
TODAY:
260 million tonnes per year
AAAA!! Plastic lasts FOREVER!!
SAVE THE EARTH
GM

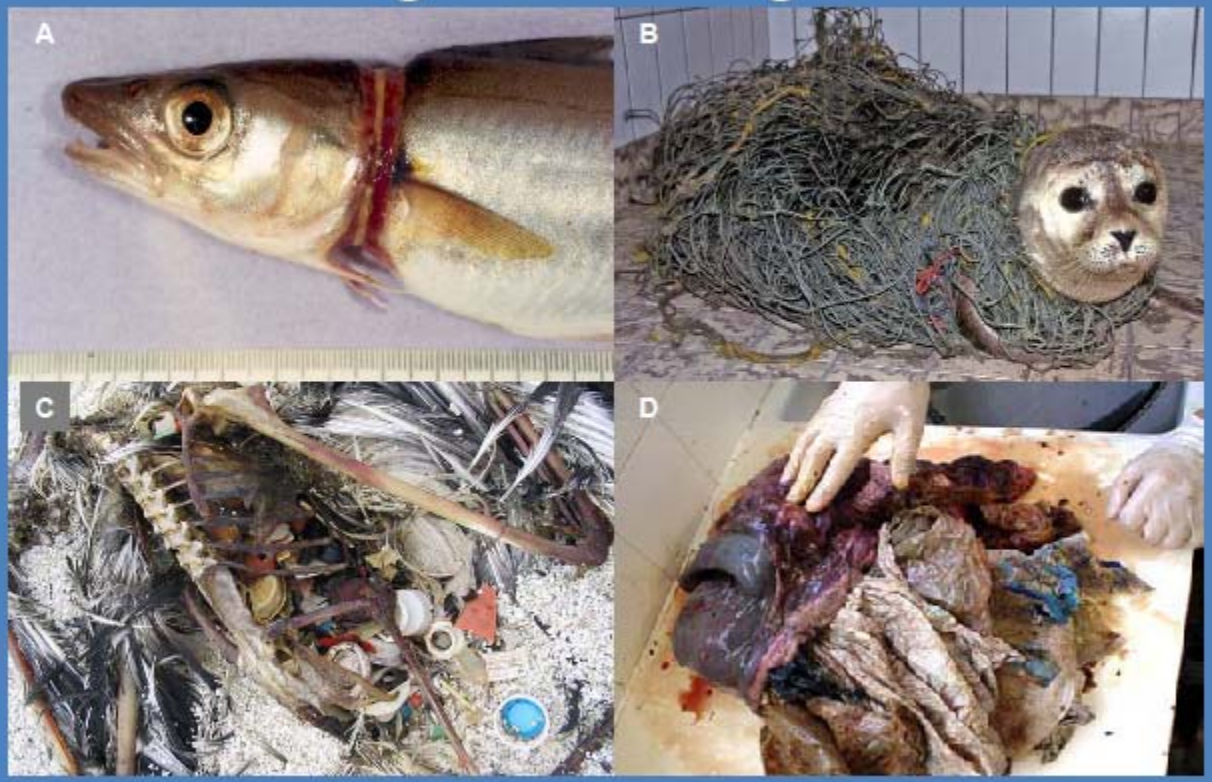
Marine Debris Sizes and Impacts



Some Potential Sources and Pathways for Plastic to Reach the Ocean

- Near-shore or near-river disposal of garbage
- Uncontrolled landfills
- Marine disposal of shipboard waste
- Beach litter
- Sewage
- Urban runoff
- Agricultural runoff
- Deposition of air emissions
- Urban dust

> 260 species affected by entanglement / ingestion

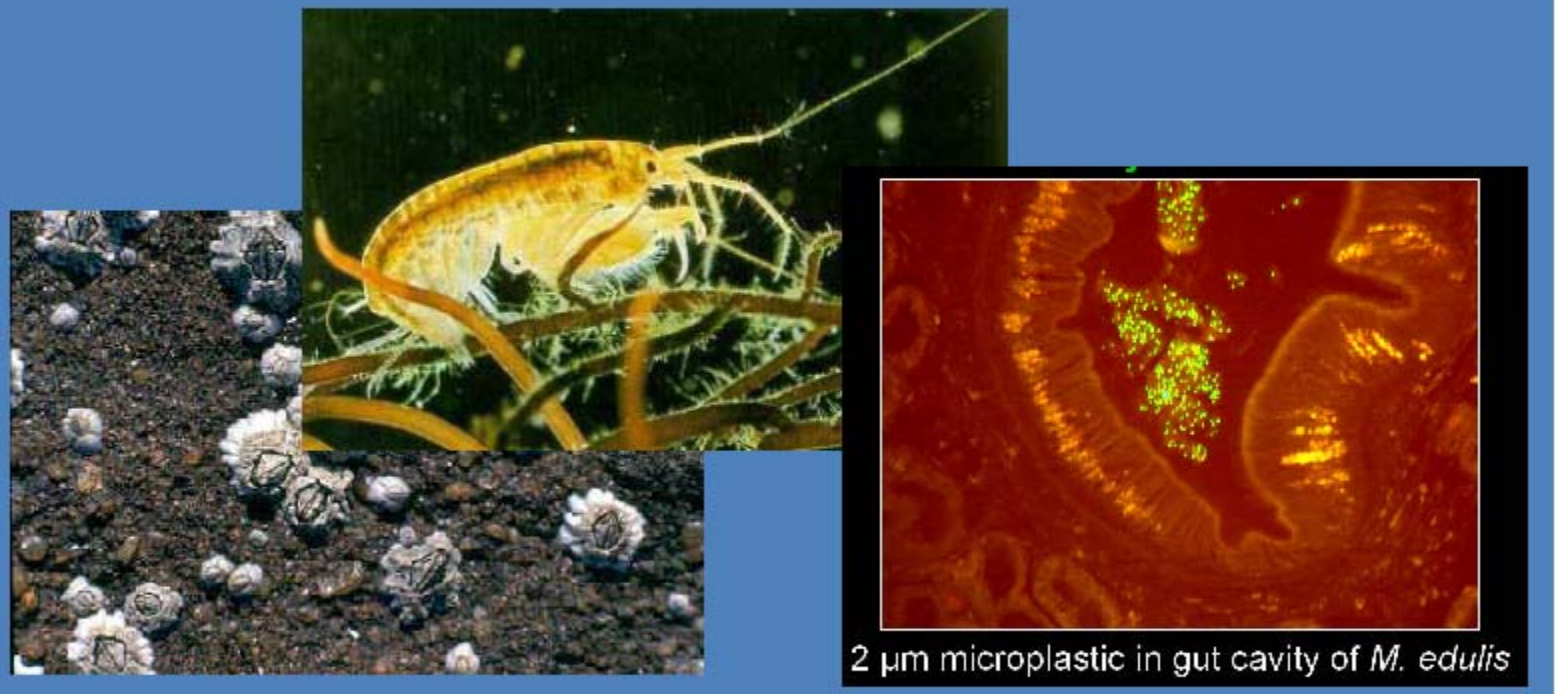


'Problems of marine debris are manifold, widely acknowledged and difficult to address'. (Gregory 2009).

Fragments in stomach of birds & fish

van Franeker *et al.* 2005

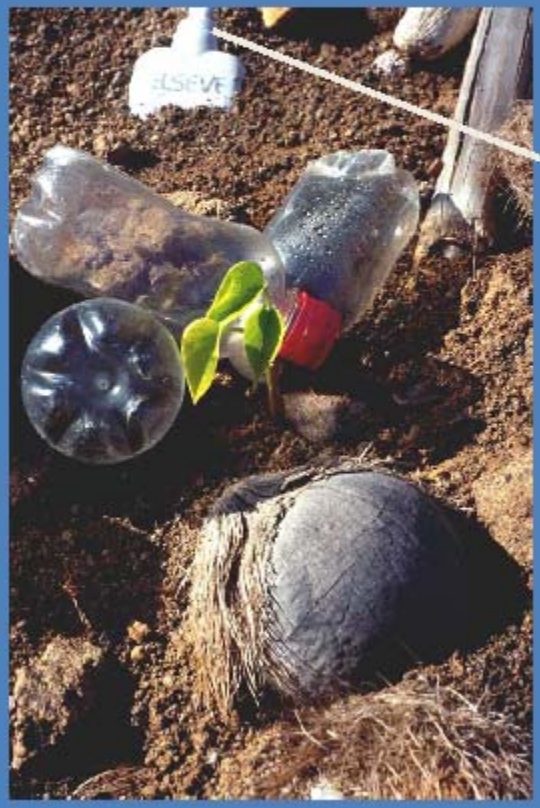
Microplastic ingested / retained



2 µm microplastic in gut cavity of *M. edulis*

Browne et al 2008, *Environmental Science and Technology*

Impacts of plastic debris



Transport invasive species
molluscs, crustaceans, bryozoans
travel long distances on floating debris

Barnes *et al.* 2005, *Marine Biology*

Benefits of plastics

'Any future scenario where plastics do not play an increasingly important role in human life therefore seems unrealistic' (Andrady & Neal 2009).

Plastics: the problems

Plastic lasts for

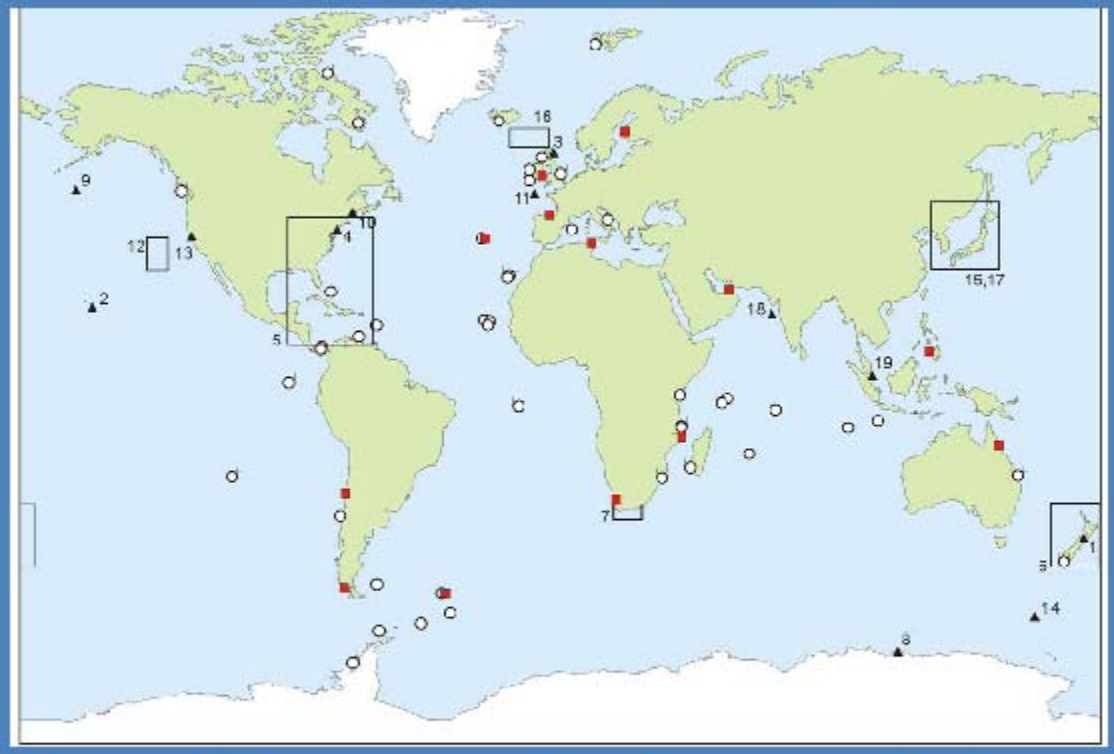
100 years ?

1000 years ?

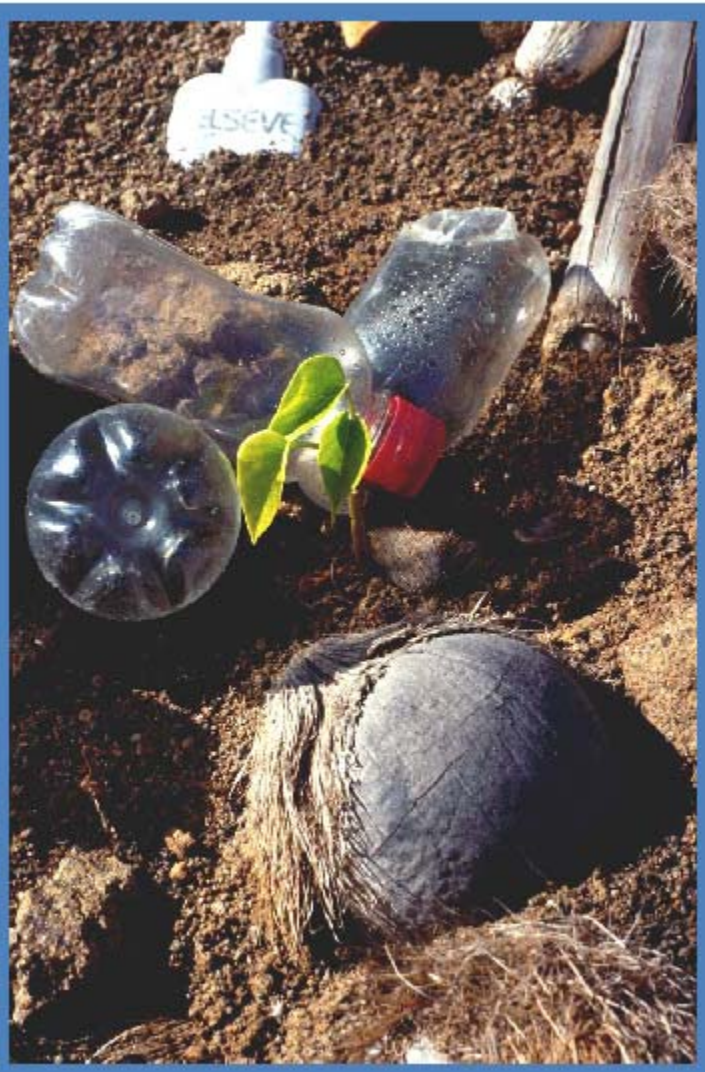
10000 years ?

End of life plastic is accumulating

Plastic debris is a global problem



One of the most ubiquitous and long-lasting recent changes to the surface of our planet is the accumulation and fragmentation of plastics' (Barnes et al. 2009).



Familiar types of debris

Disposable packaging, rope, netting

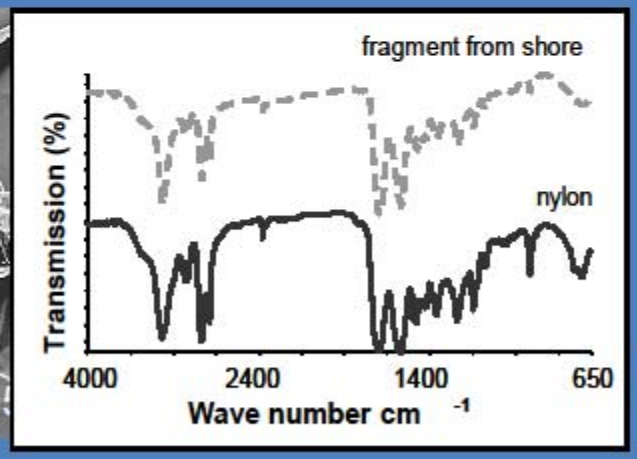
Less familiar - microplastic debris ?

Thompson *et al.* 2004 fragments visible with x30 microscope >20µm

Browne *et al.* 2007 suggest microplastic defined as <1mm

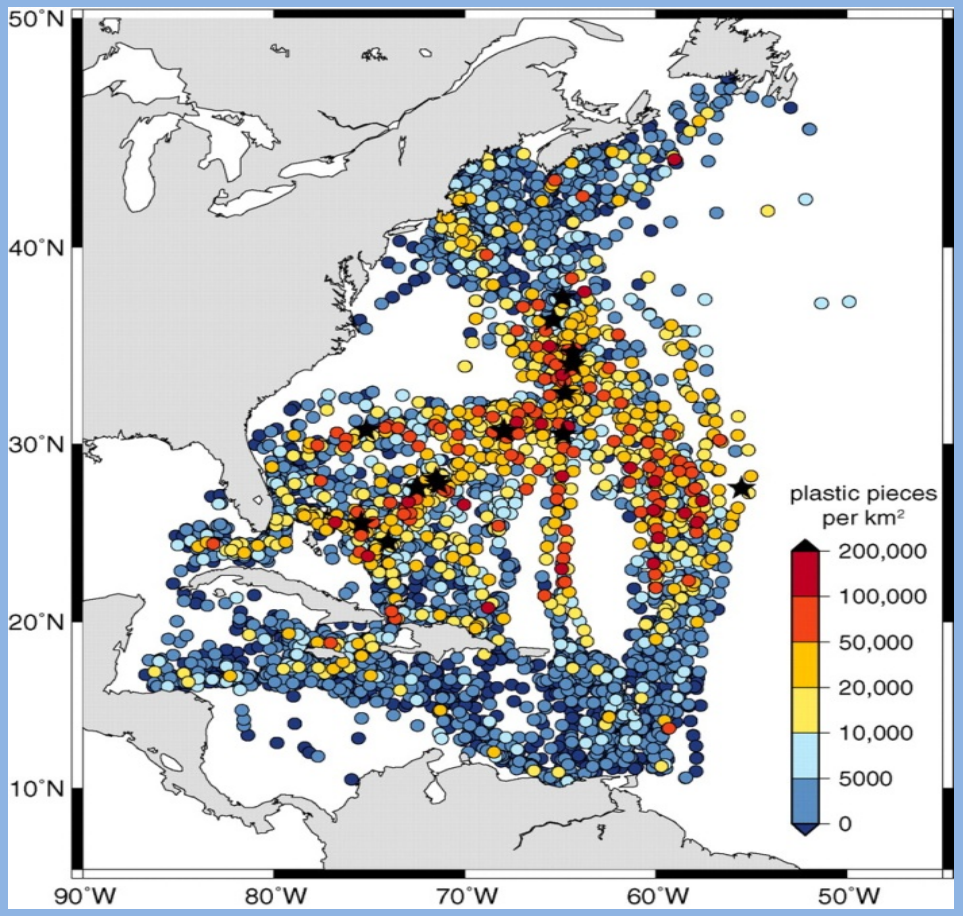
Smallest reported fragments 1.6µm (Ng & Obbard 2006)

Arthur *et al.* NOAA workshop, 2009 < 5mm



Part of a continuum – very small end of the debris size distribution

Marine Debris Plastics in the Western North Atlantic Ocean 1986 - 2008



Distribution of plastic marine debris collected in 6136 surface plankton net tows on annually repeated cruise tracks from 1986 to 2008 in the western North Atlantic Ocean and Caribbean Sea. [Sea Education Association, Woods Hole, MA] *K L Law et al. Science 2010;329:1185-1188*

Plastic distribution with latitude, Law *et al.* (2010) *Science*

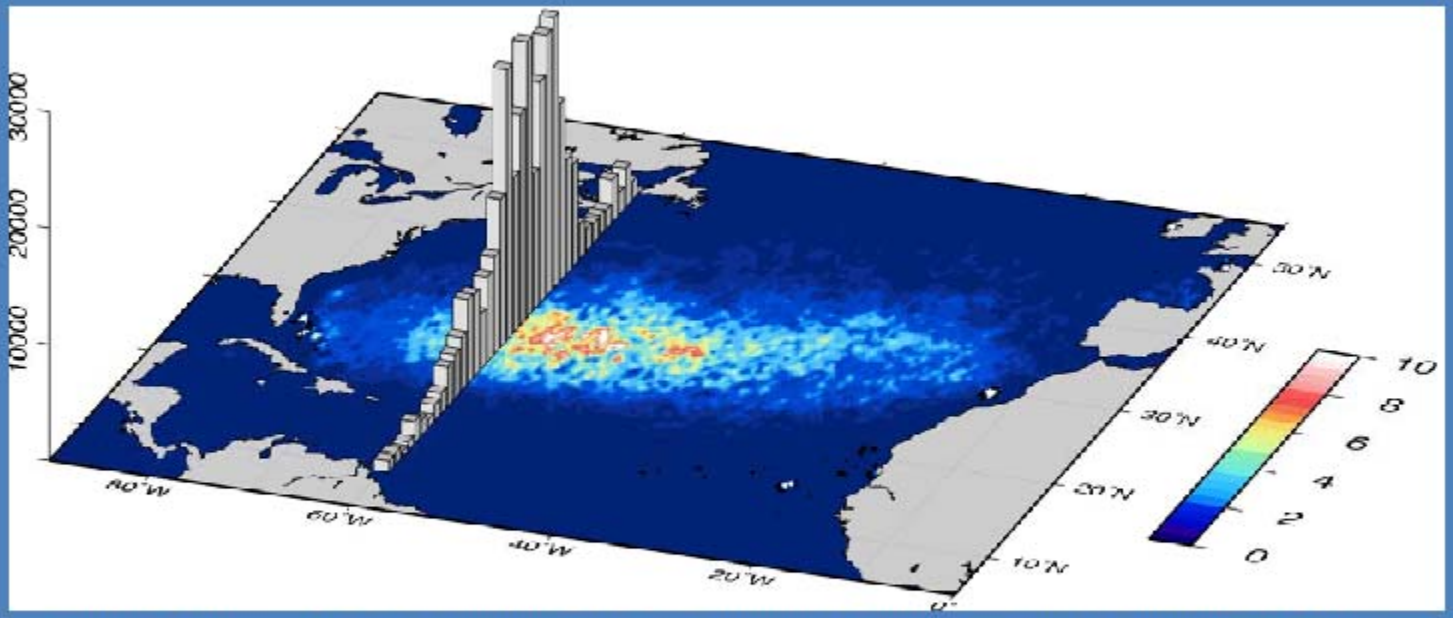
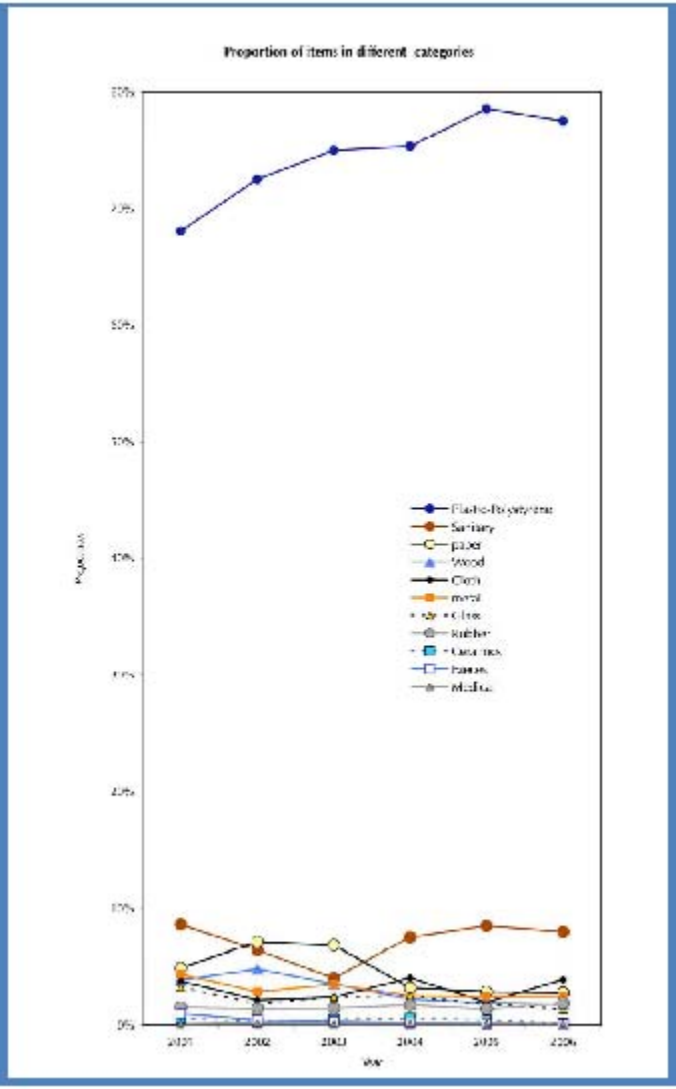


Figure S2: Average plastic concentration as a function of latitude for data shown in Fig. 1 (bars, units of pieces km-2), and concentration, C (color shading), of initially homogeneous (C=1) surface tracer after 10-year model integration (*S2*). *Averages and standard errors (Fig. S1) were computed in one-degree latitude bins. The highest plastic concentrations were observed in subtropical latitudes (22-38°N) where model tracer concentration is also a maximum.*



3) Changes in the composition of marine debris items on reference beaches during the six-year period, OSPAR 2009

Sources of microplastic

1) Fragmentation of conventional plastics

mechanical action, abrasion, UV enbrittlement

2) 'degradable' and 'biodegradable' plastics

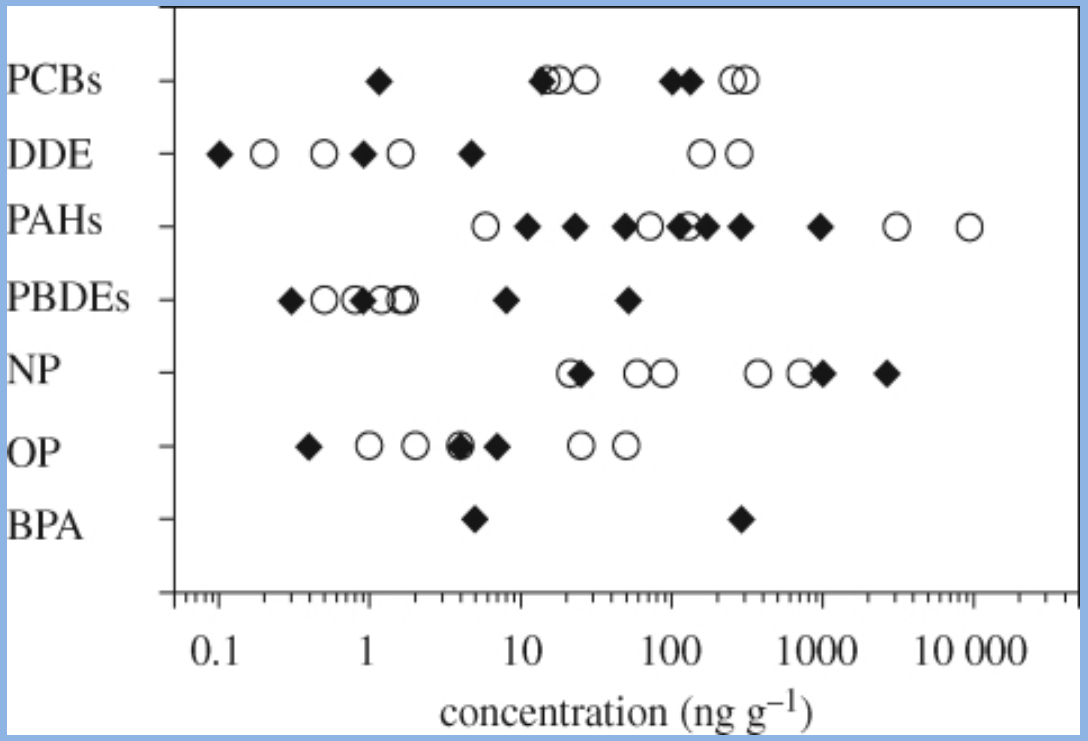
(EN 13432, ASTM D6400-99) = pre shredded plastic degrades in commercial composting plant in 180 days, 56 – 71 ºC, 50-60% humidity, aerobic, pH 7-8

indirect introduction of particles

Types of Toxic Chemicals that may be Associated with Marine Debris

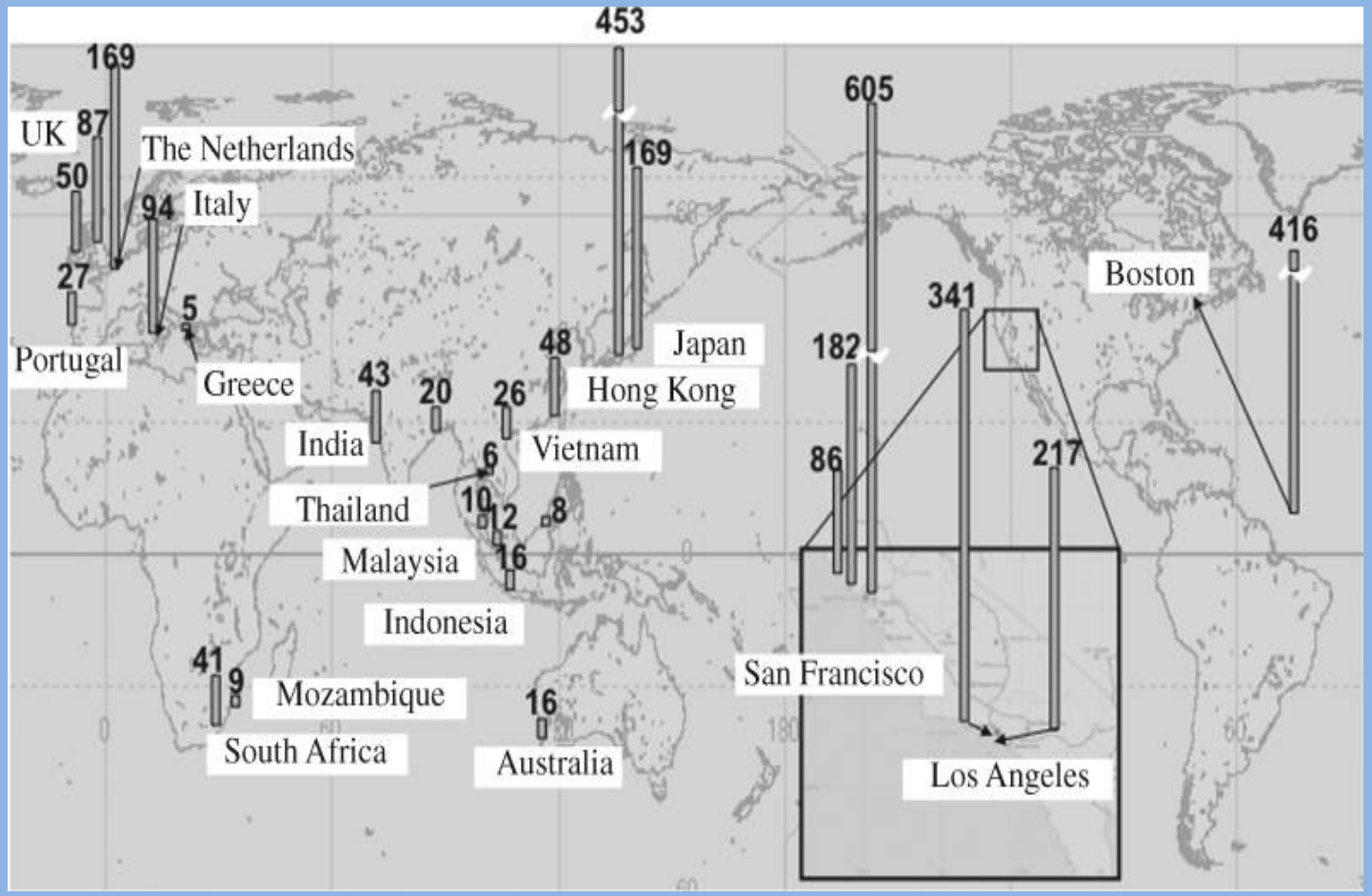
- Legacy chemicals from chemicals management problems
  - PCBs, DDT/Chlorinated Pesticides
- Currently released chemicals that persist and migrate through/accumulate in environment
  - PBDEs/BFRs, Perfluorochemicals, DDT, Triclosan, PAHs
- Chemical additives that may leach out of the plastic
  - Phthalates, Nonylphenol
- Chemical breakdown products from the plastic itself
  - Bisphenol-A, Styrene oligomers
- Naturally occurring chemicals
  - PAHs

POPs and Chemicals Associated with Plastic Ingredients Extracted from Plastic Pellets



Concentrations of organic contaminants in marine plastic debris fragments from the North Pacific Central Gyre and Japanese coast of the Pacific Ocean. [Takada]

PCBs in Beached Plastic Pellets



Concentrations of PCBs (ng g^{-1} pellet) in beached plastic pellets (E. Teuten et al., 2011).

Adsorption of Persistent Chemicals to Plastic

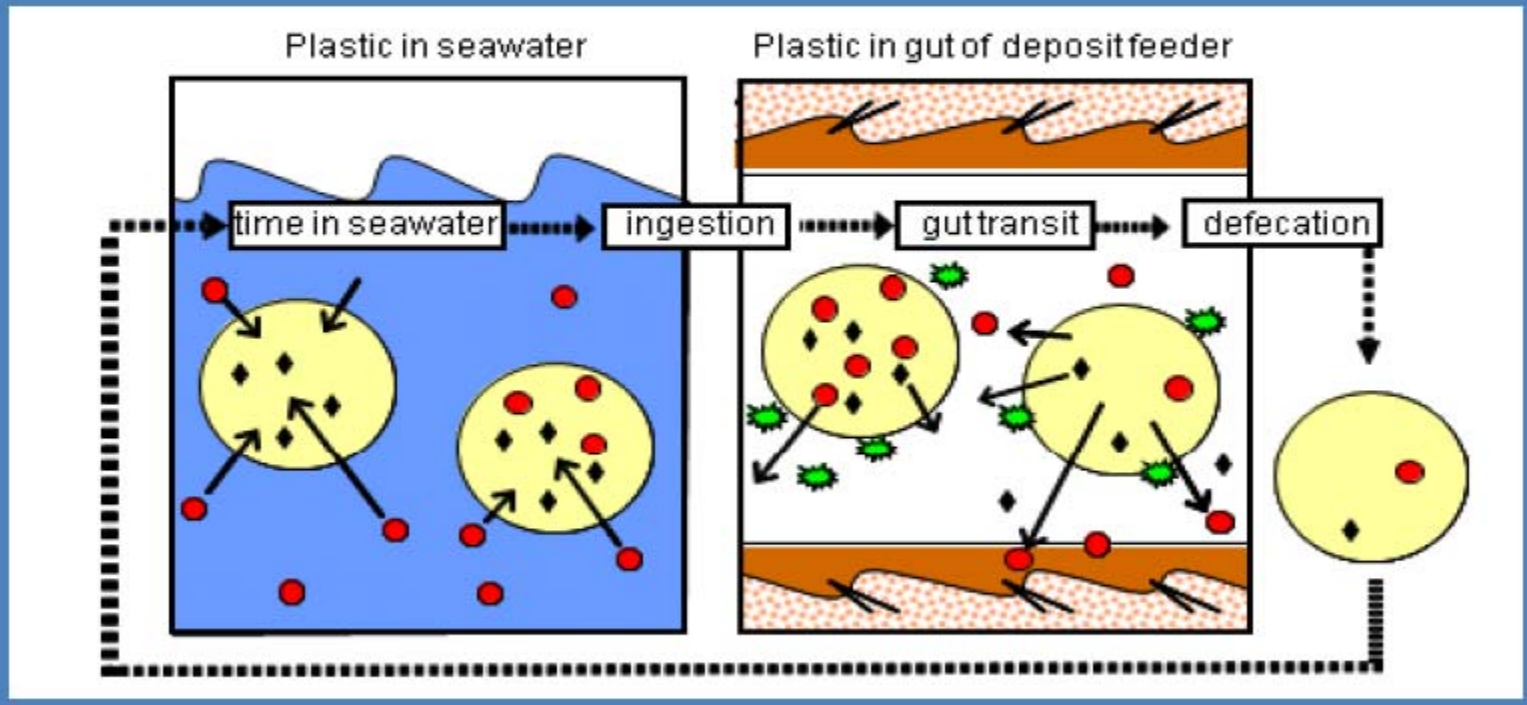
- A variety of PBTs adsorb strongly to plastics found in the marine environment
- Large differences in concentrations between locations and between individual plastic pieces at a single location.
- PBTs potentially can partition between plastic and many other environmental compartments, e.g., air, SSM, colloidal particles, DOM, biota, subsurface seawater, marine snow, sediment, benthic organisms
- Kinetics of adsorption/desorption between plastics and biota

Adsorption of Persistent Chemicals to Plastic

- Marine debris plastic is likely not the primary transport mechanism of PTS to Arctic, but implications for food chain and transport to other areas unclear. Takada work on pellets suggests that amount adsorbed may depend on local or regional contamination levels.

- Questions remain regarding transfer of chemicals from plastics to biota. Transfer from plastic to biota has been shown experimentally and in models. However, a recent model suggests partitioning is sensitive to the parameters.

Conceptual model - uptake of contaminants from plastics by marine organism



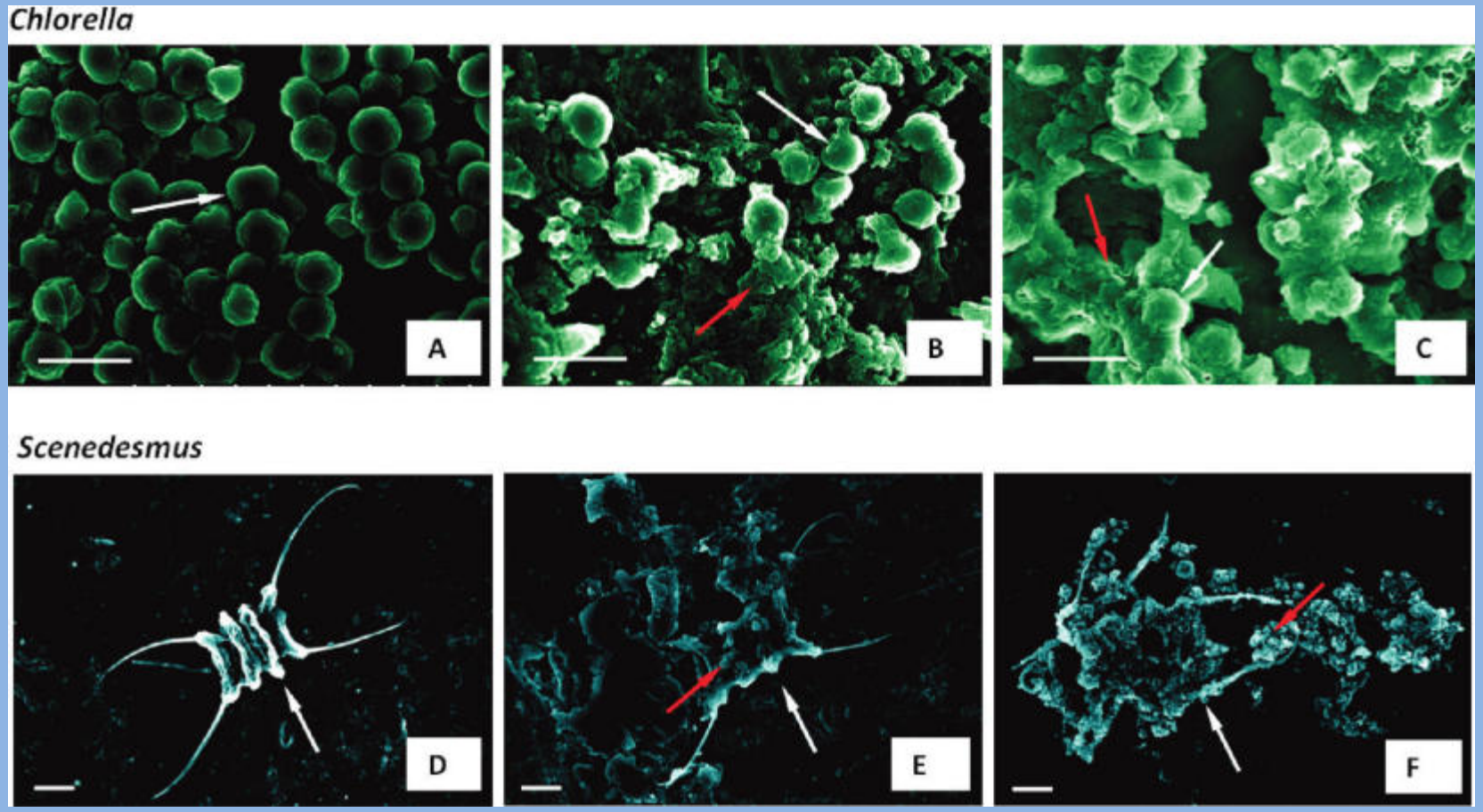
Plastics Additives

- Plastics generally contain functional additives. For example, plasticizers (e.g., phthalates), colorants, fillers, antioxidants, UV stabilizers, blowing agents, catalyst residues, brominated and other flame retardants, etc.
- Types & amounts depend on plastic and application
- Nonylphenol can be extracted from plastic pellets
- Little is known about the properties and fate of additives and their breakdown products in the marine environment as plastics age and fragment

Chemicals Resulting from Polymer Breakdown

- Polycarbonate has been reported to exhibit slow degradation under environmentally relevant conditions to release BPA
- It has been suggested that polystyrene degrades in the environment with release of styrene monomer, dimer, and trimer
- PET and Polyurethane have also been reported to undergo weight loss under biofouling conditions

Adsorption of Charged Polystyrene Beads onto the Surface of Algae



Inhibits photosynthesis; potential oxidative stress

Nanoparticles and Marine Debris Chemistry

- Little is known about whether microdebris continues to break down to form nanoparticle-sized debris
- Nanoparticles have chemical as well as physical effects
- Nano-polystyrene (NPS) beads can adsorb onto surface of algae, affecting photosynthesis (Bhattacharya, et al, 2010)
- NPS beads can form aggregates that can be taken up by bivalves and retained in the gut longer than larger particles (Ward & Kach, 2009)

A Better understanding is Needed of Marine Debris Problems and Potential Long-Term Solutions

What dangers to the ocean lurk out of sight or unknown?

Who can speak for the sea?

Science gaps: impacts of plastics on chemicals

- What is the local distribution of chemical pollution associated with microplastics (vertical and horizontal)?
- What are mechanisms of adsorption/release of chemicals on different types of plastics?
- Do PBT chemicals associated with plastics debris transfer to organisms and selective biomagnification?
- Does plastic break down into nano-sized particles?
- What is extent, fate, transport, toxicity of nano-sized plastic marine debris?
- How do we prevent that which cannot be corrected?